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Forecast and Plan for Energy Use based on Economic Perspective

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Abstract: With the rapid development of economy, energy has become an indispensable part of daily economic operation. However, with the depletion of resources, more and more countries have paid attention to the production and use of renewable energy. In this paper, based on US energy use and TOPSIS methods, we selected the best clean energy states in the four US states in 2009. Then, we built the DDEPM model to predict the energy profile of each state in 2025 and 2050. Based on this, we have established a Multi-objective programming model to determine the target of renewable energy use. Finally, we give the corresponding action recommendations.

Keywords: TOPSIS methods; DDEPM model; Multi-objective programming model; Renewable energy

1. Introduction

This question requires us to choose the states with the best use of clean and renewable energy in the four states of 2009. At first, we analyze the best and select the reasonable evaluation index. Then, based on TOPSIS, we comprehensively evaluated the consumption of clean and renewable energy in four states.

1.1. Model preparation

Selection of model index system:
We can think of best as the highest proportion of clean and renewable energy in four states and the best use of it. Combined with relevant analysis, we selected the GDP ($10,000), clean energy proportion, energy consumption per thousand dollars of GDP, and energy consumption per capita as the evaluation index.
Data searching and sorting:
From the federal bureau of statistics website, we collected data on the GDP and population of four states in 2009. Combined with relevant data, we sorted out indicators such as clean energy consumption, energy consumption per thousand dollars of GDP, and energy consumption per capita. The results are shown in the Table 1.

Table 1. Parameter Values

	GDP Million Dollars	Clean Energy Ratio	Energy Consumption per Dollar of GDP, Btu	Energy Consumption per Capita, Btu
AC	191211500	0.1226	0.0304	0.1573
ZA	24250900	0.1395	0.0306	0.117
NM	8283800	0.0775	0.0555	0.2256
TX	116651600	0.0453	0.0674	0.3305

1.2. Model establishing—comprehensive evaluation of clean energy based on TOPSIS method

Model principle:
Ideal solution is an effective multi - index evaluation method. With the ideal solution and negative ideal solution of multi-attribute problem, it can be used for the sorting of each scheme. The TOPSIS method is a virtual optimal solution, and its various index values reach the optimal value in the evaluation object. However, the negative ideal solution is the worst solution of the virtual reality, and its various indexes reach the worst value in the evaluation object. The central idea is to find a point which is as close as possible to the ideal point in the Euclidean space, so that the distance from the ideal point evaluation function is the smallest, and the distance from the anti-ideal point evaluation function is the largest.
Preprocessing of raw data:
The variables x_1, x_2, x_3, and x_4 respectively represent the index variable GDP ($10,000), clean energy share, energy consumption per thousand dollars of GDP, and energy consumption per capita. Among them, the benefit type index is x_1, x_2, the cost type index is x_3, x_4.
There are four evaluation objects: California (AC), Arizona (AZ), new Mexico (NM), and Texas (TX). The index variable x_{ij} is denoted as a_{ij}, and the corresponding data matrix is $A=\left(a_{ij}\right)_{4\times4}$.

The standardized processing of the effective indicators is as follows:

$$\tilde{x}_j = \frac{x_j^{max} - x_j}{x_j^{max} - x_j^{min}}, j = 1,2 \quad (1)$$

The standardized processing of cost indicators is as follows:

$$\tilde{x}_j = \frac{x_j - x_j^{min}}{x_j^{max} - x_j^{min}}, j = 3,4 \quad (2)$$

In the formula: x_j^{max} is the maximum value of the value of the j index variable. x_j^{min} is the maximum value of the value of the j index variable. The standardized data matrix is denoted as $B = (b_{ij})_{4\times4}$ We substitute the data into B, and the data matrix is:

$$B = \begin{pmatrix} 1 & 0.09 & 0 & 0.59 \\ 0.82 & 1 & 0.34 & 0 \\ 1 & 0.99 & 0.32 & 0 \\ 0.81 & 1 & 0.49 & 0 \end{pmatrix}.$$

1.3. Solution of model

The solution of positive and negative ideal values

The formula for the positive ideal solution is

$$C_j^* = \max_{1\le i\le 4} b_{ij}, j = 1,2,3,4 \quad (3)$$

The formula for the negative ideal solution is

$$C_j^0 = \min_{1\le i\le 4} b_{ij}, \ j = 1,2,3,4 \quad (4)$$

So we know that the positive ideal solution is $C_j^* = 1$, and the negative ideal solution is $C_j^o = 0$.

Evaluate the distance between each evaluation object and the positive ideal solution

$$d_i^* = \sqrt{\sum_{j=1}^{4}\left(b_{ij} - c_j^*\right)^2}, i = 1,2,3,4 \quad (5)$$

$$d_i^0 = \sqrt{\sum_{j=1}^{4}\left(b_{ij} - c_j^0\right)^2}, i = 1,2,3,4 \quad (6)$$

Comprehensive assessment of each state

$$f_i^* = d_i^0 \big/ \left(d_i^0 + d_i^*\right), i = 1,2,3,4 \quad (7)$$

We substitute the data matrix B and the positive and negative ideal solutions and use the MATLAB program to find the comprehensive evaluation values of the four states. The results are shown in Table 2.

Rank the four states according to the size of the comprehensive value.

Table 2. A Comprehensive Evaluation Index of Four States

	California	Arizona	New Mexico	Texas
d_i^*	0.2602	0.9127	1.4663	1.7794
d_i^0	1.8254	1.7312	0.6803	0.5924
f_i^*	0.8752	0.6548	0.3169	0.2498

The four states have a clean and renewable energy ranking: California, Arizona, New Mexico and Texas. So, the state with the best clean and renewable energy use is California.

2. Energy Forecasting Profile for Each State

2.1. Problem analysis

The question asked us to forecast the energy profiles of the states in 2025 and 2050 based on past state data. Based on previous analysis, we conclude that there is a large correlation between GDP, population, and industrial output and energy use in each state, And its concrete correlation has been drawn in the neural network model. Due to the large historical data of GDP, population and industrial output of each state, and with strong stability, it is more suitable for long-term prediction. Based on relevant analysis, firstly, we use the discrete second-order difference equation prediction model to predict GDP, population and industrial output in each state, and continue to debug the model to produce the data that is closest to the actual situation. After getting the GDP, population and industrial output forecast of each state, we substitute it into the neural network model to predict the energy use of each state, and then we can forecast the state energy in 2025 and 2050.

2.2. DDEPM model establishment

The advantage of DDEPM is the higher prediction accuracy of turning points (inflection points). Therefore, we use the DDEPM method to model. DDEPM modeling process shown in Figure 1.

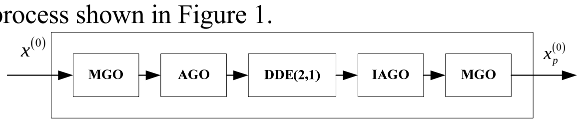

Figure 1. The modeling steps for the DDEPM prediction model

Step 1: MGO. Let B represent the original sequence, B represents the sequence after the MGO operation, which can be defined as B：

$$x_m^{(0)} = \left\{x_m^{(0)}(1), x_m^{(0)}(2), x_m^{(0)}(3), \cdots, x_m^{(0)}(n)\right\}$$

$$x_m^{(0)}(i) = MGO\left(x^{(0)}(i)\right) = s + \gamma \times x^{(0)}(i),\ i = 1, 2, \cdots, n \quad (8)$$

Where: n is the number of the original sequence, s is the displacement factor, γ is the scale factor, $x^{(0)}(i)$ is the first series of the i of data. Step 2: 1-AGO Operation. Let $x^{(1)}$ be a cumulative time series generated by $x_m^{(0)}$, then $x^{(1)}$ may be expressed as follows:

$$x^{(1)} = \left\{x^{(1)}(1), x^{(1)}(2), x^{(1)}(3), \cdots, x^{(1)}(n)\right\} \quad (9)$$

$$x^{(1)}(p) = \sum_{i=1}^{p} x_m^{(0)}(i), p = 1, 2, \cdots, n$$

Step 3: modeling with univariate second-order difference equations $DEE(2,1)$. Using the univariate second-order difference equation, we model the series of cumulatively generated ones. The modeling equation is as follows:

$$x^{(1)}(p+2) + a \cdot x^{(1)}(p+1) + b \cdot x^{(1)}(p) = 0 \quad (10)$$

（undetermined coefficient is a and b, p is an integer）

We use linear least square error estimates to evaluate undetermined coefficients a and b, then step 4: solving the univariate second o $\Theta = \left(X^T X\right)^{-1} X^T Y$ rder difference equation. Substituting $x^1(p) = r^p$, then we can get formula as follows:

$$\begin{aligned} & r^{p+2} + a \cdot r^{p+1} + b \cdot r^p = 0 \\ & r^p\left(r^2 + a \cdot r + b\right) = 0 \end{aligned} \quad (11)$$

Then, $r_1 = \frac{-a + \sqrt{a^2 - 4b}}{2}$, $r_2 = \frac{-a - \sqrt{a^2 - 4b}}{2}$. When $r_1 \neq r_2$, the second-order difference equations are different. Step 5: IAGO. Since the discrete difference equation prediction model is based on a sequence of numbers generated by the cumulative modeling, so we must use the inverse cumulative addition operation to restore the original sequence, The calculation is as follows:

$$\hat{x}^{(0)} = x^{(1)}(p) - x^{(1)}(p-1) \quad (12)$$

($\hat{x}^{(0)}$ indicates the predicted value, p is the predicted step)

Step 6: IMGO. Since the original sequence is generated by the mapping before an accumulation is generated, we must generate the true prediction by inverse mapping. The inverse mapping generation operation can be expressed as follows:

$$x_p^{(0)} = IMGO\left(x_p^{(0)}\right) = \frac{1}{\gamma}\left(\hat{x}_p^{(0)} - s\right) \quad (13)$$

2.2.1. Forecast of population, GDP and industrial output in 2025 and 2050

Taking California's population projections as an example, we use the 1950-2009 data as the original series. After MGO and 1-AGO operations, we estimate the coefficients a = -2.1835, $b = 1.1940$ using the linear least square error. The DEE (2,1) equation is:

$$x^{(1)}(p+2) - 2.1835 \cdot x^{(1)}(p+1) + 1.1940 \cdot x^{(1)}(p) = 0 \quad (14)$$

Based on this model, we calculated that the population of California in 2025 was 40091.44 thousand. The forecast results of other indicators are shown in Table 3.

Table 3. Predictions in Four States

STATE	INDEX	2025	2050
CA	GDP(Million Dollars)	3412389.01	3584553.03
	POP.(Thousands)	40091.44	42426.32
	IND.(Million Dollars)	450458.86	452008.36
AZ	GDP(Million Dollars)	540182.68	576542.32
	POP.(Thousands)	7786.85	8990.79
	IND.(Million Dollars)	67868.07	56774.00
NM	GDP(Million Dollars)	97407.68	123097.93
	POP.(Thousands)	2058.15	2224.60
	IND.(Million Dollars)	20716.60	19111.23
TX	GDP(Million Dollars)	1735770.61	1830769.40
	POP.(Thousands)	27534.14	28876.36
	IND.(Million Dollars)	475625.32	386655.22

2.2.2. Projections of energy profiles for 2025 and 2050

We put the above forecast results of GDP, population and industry in 2025 and 2050 into the respective RBF models. It can be concluded that the final energy profile for each state is formed without any policy change in the governor's office in each state.

The specific situation is shown in Table 4.

Table 4. 2025 and 2050 Energy Profiles

STATE	YEAR	CLTXB	NGTXB	PMTCB	RETCB	TOTAL
CA	2025	37863.61	1664642.2	5474452.46	845296.8	8022255.07
	2050	13444.96	1732512.64	3861755.36	796567.18	6404280.14
AZ	2025	23469.89	91500.8	741911.62	76860.23	933742.54
	2050	14307.19	124027.72	555180.61	107269.43	800784.95
NM	2025	1199.81	240283.08	308184.74	11762.05	561429.68
	2050	2481.62	177914.08	229522.68	10669.13	420587.51
TX	2025	73896.95	2861510.4	5286463.08	121877.55	8343747.98
	2050	68888.8	2903297.92	5180855.79	125200.38	8278242.89

3. Problem Analysis

This Question asks us to set the goal of renewable energy in 2025 and 2050 for each state based on the criteria of the best profile and forecast data and to advise on the achievement of the energy tightening targets in all four states. First, we establish the values for energy efficiency in 2025 and 2050 based on literature. Then, after obtaining the projections for 2025 and 2050, we determined the energy requirements for the two years and established a multi-objective programming model based on the price data extracted from the various energy sources in the annex. Finally, we find the energy cooperation goals of the four states in order to achieve the best collective effect.

3.1. Data processing

After extensively reading the documents of the international conference, we found out the "Climate and Energy 2030 Policy Framework" and other documents. After drawing lessons from it, it is concluded that the energy efficiency in the United States in 2025 and 2050 should be increased by 20% and 30% respectively on the existing basis. We extract the prices of the coal, natural gas, oil and renewable resources of the states from the annexes to the questions so as to provide a data basis for the establishment of goals.

3.2. Multi-objective programming model establishment

The purpose of the contracts signed by the states is to increase the use of renewable energy and maximize economic welfare. However, during the process of signing the contract and cooperating, the states should fully consider the cost factor and should not blindly increase their use of renewable resources. As a result, states pursuing the expanded use of renewable energy should use minimum costs as a basic constraint. To address the goals of using renewable energy in four states, we built a multi-objective programming model.

Let D be the price matrix for coal, gas, oil and renewable energy in California, Arizona, New Mexico, Texas, that is:

$$D=\begin{pmatrix} d_{11} & d_{12} & \cdots & d_{14} \\ d_{21} & d_{22} & \cdots & d_{24} \\ \vdots & \vdots & \ddots & \vdots \\ d_{41} & d_{42} & \cdots & d_{44} \end{pmatrix}. \tag{15}$$

Let G be the state's consumption matrix for all four energy sources, that is:

$$G=\begin{pmatrix} g_{11} & g_{12} & \cdots & g_{14} \\ g_{21} & g_{22} & \cdots & g_{24} \\ \vdots & \vdots & \ddots & \vdots \\ g_{41} & g_{42} & \cdots & g_{44} \end{pmatrix}. \tag{16}$$

The multi-objective programming model is established as follows。

Where: q_i is the predicted energy use of the year, u is the energy efficiency, and h is the GDP of the forecast year.

3.3. Solution to the model

We bring the forecast data and the historical data of 2025 and 2050 respectively into the multi-objective programming model and finally get the energy use target of 2025. The results are shown in Table 5.

As we can see from Table 5, California has a large share of renewable energy consumption; both Arizona and Texas have seen increased use of renewable energy. In addition, comparing the energy use target of 2050 with that of 2025, we can find that the total energy use of all four states has declined, and that both the proportion of renewable energy use and that of renewable energy use have greatly increased. So this goal is more ideal.

$$\min Z_1 = D \cdot G = d_{11}g_{11} + d_{12}g_{12} + \cdots + d_{44,44}g_{44,44}$$

$$\max Z_2 = \frac{g_{14}+g_{24}+g_{34}+g_{44}}{\sum_{i=1}^{4}\sum_{j=1}^{4} g_{ij}} \tag{17}$$

$$s.t.\begin{cases} g_{11}+g_{21}+g_{31}+g_{41} \le q_1 \\ g_{12}+g_{22}+g_{32}+g_{42} \le q_2 \\ g_{13}+g_{23}+g_{33}+g_{43} \le q_3 \\ g_{14}+g_{24}+g_{34}+g_{44} \le q_4 \\ \sum_{i=1}^{4}\sum_{j=1}^{4} g_{ij} = u \cdot h \end{cases}$$

Table 5. 2025 and 2050 Energy Use Goals of the Four States

STATE	YEAR	CLTXB	NGTXB	PMTCB	RETCB	TOTAL	RETCB/TOTAL
CA	2025	30370.08	541962.19	2346858.22	1078046.59	3997237.08	0.2697
	2050	8288.06	405397.8	961315.22	610832.71	1985833.79	0.3076
AZ	2025	23215.12	62571.78	606982.18	120238.17	813007.25	0.1479
	2050	13443.9	117278.03	425729.92	172962.35	729414.2	0.2371
NM	2025	940.33	188318.61	192904.43	29218.35	411381.72	0.071
	2050	1529.78	120384.62	152031.66	35631.67	309577.73	0.1151
TX	2025	69418.68	2102511.87	3640226.79	876287.75	6688445.09	0.131
	2050	46856.67	1469335.91	3523906.06	951531.67	5991630.31	0.1588

4. Targeted Advice

Based on the foregoing, we recommend that the four states take the following three actions to achieve the goal of a compact energy contract.

4.1. Price incentives

We propose that all states should form a sales model based on their own renewable energy development, technological level and economic development to propose the price of renewable energy products and voluntary subscription by consumers. As long as all kinds of price policies are properly formulated, they can raise the technical level, promote market development and reduce costs.

4.2. Work together to develop renewable energy

States should jointly establish state-level laboratories and research centers to provide technical support for R & D of renewable energy. State governments should also provide agencies, businesses with technical guidance, research and development funding and subsidies to support the development of the renewable energy industry.

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